INTEGRATED PROCESS, FINANCIAL, AND RISK MODELING OF CELLULOSIC ETHANOL FROM WOODY AND NON-WOODY FEEDSTOCKS VIA DILUTE ACID PRETREATMENT

Trevor Treasure, Ronalds Gonzalez, Hasan Jameel, Richard B. Phillips, Steve Kelley

North Carolina State University, Department of Forest Biomaterials

2820 Faucette Dr.

Raleigh, NC, USA

trevor_treasure@ncsu.edu

Dilute sulfuric acid pretreatment followed by enzymatic hydrolysis and fermentation is a technology widely studied as a potential pathway for conversion of lignocellulosic biomass to ethanol. Six feedstocks, three woody and three non-woody, were evaluated in process and financial simulations. The woody feedstocks include natural hardwood, Eucalyptus, and loblolly pine while the non-woody feedstocks include corn stover, switchgrass, and sweet sorghum. A complete process model was developed in WinGEMS which provided the material and energy balances necessary for financial analysis. Based upon experimental and literature data, ethanol yields for the non-woody feedstocks range from 321-330 liters per bone dry metric ton of biomass (L/BDt). Sweet sorghum that has been pressed and washed to remove soluble sugars prior to dilute acid processing can have an ethanol yield of approximately 471 L/BDt but additional front end capital expenditure (CAPEX) is required to modify the traditional dilute acid process. Natural hardwood and Eucalyptus produce ethanol yields of 342 and 317 L/BDt respectively. Loblolly pine is especially recalcitrant and only yields 108 L/BDt, this feedstock produces excess electricity of approximately 440 kWh/BDt biomass processed.

When processing 700k bone dry metric tons per year, the non-woody feedstocks have lower minimum ethanol revenues to achieve a 12% internal rate of return ($MER_{@12\%}$) than the woody feedstocks. The non-wood $MER_{@12\%}$ ranged from \$0.69-\$0.77/liter while the $MER_{@12\%}$ for natural hardwood and Eucalyptus was \$0.82/liter. The $MER_{@12\%}$ for loblolly pine is higher than reasonable limits at \$2.25/liter due to the low ethanol yield. The risk analysis of this technology and feedstocks indicates that financial success is generally driven by ethanol revenue, biomass cost, and ethanol yield although loblolly pine is especially sensitive to electricity whole sale price. The impact of feedstock composition variability on the net present value ($NPV_{@12\%}$) was estimated for corn stover, switchgrass, and loblolly pine. One standard deviation in the sample carbohydrate content for corn stover, switchgrass, and loblolly pine will impact the $NPV_{@12\%}$ by approximately \$40M, \$60M, and \$24M respectively. If recent historical cost and revenue variability continues for the life of the project the most attractive feedstock is squeezed sweet sorghum where the probability of achieving at least a 12% internal rate of return is 64%. The likelihood of attaining at least a 12% internal rate of return for the other biomass types through this conversion pathway is low enough to discourage financial investment under the current assumptions.